PRINCIPLES OF REFLEX ACTION.

PRINCIPLES OF REFLEX ACTION.[1]

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Living beings are brought into relation with their environment by means of many different vital processes, amongst which responses to stimuli hold an important place. From the wide realm of nature numberless examples may be taken. Some of these are comparatively simple in their nature. The mimosa, or sensitive plant, folds its leaves on irritation of any kind. You are all acquainted with the scarlet pimpernel, better known perhaps as the poor man's weather-glass. When the weather is dark and lowering, this fair little flower closes its petals and waits till the clouds pass; but so soon as the sky clears, it unfolds its floral envelope and expands in the sunshine. The actinia, or sea-anemone, draws in its rays and shuts its mouth when an irritant is applied to it. When a bright light falls upon the eye of one of the higher animals, the lids at once close and the pupil contracts. These are examples of responses to stimuli, culled from widely different natural domains, yet all of a very simple character.

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[1] Part of a clinical lecture delivered in the Edinburgh Royal Infirmary.

There are others, however, which are extremely complex; to one or two of these you will allow me to call your attention. They belong for the most part to the category of what have been termed the co-ordinated reflex phenomena, and are in their essence instances of complex reflex action. Many examples of such activities are to be found in the works of writers on Natural History. Let me, as an instance, mention an interesting phase in the life-history of the yucca moth, fully described by Kerner.[1] This is a beautiful silvery insect, which immediately on leaving the chrysalis flits to one of the flowers of the yucca plant, takes a quantity of pollen from the flower, and kneads it into a little ball; with this it flies off to another flower of the same kind; then with its needle-shaped pincers it bores into the lower part of the pistil, in which it deposits its eggs, and, ascending to the top of that part of the plant, it deposits the ball of pollen. Thus, by one series of acts it at once fertilises the flower and provides for the nutrition of its progeny. This, to my mind, is one of the most marvellous of the instinctive activities, as they are called; it is certainly performed without any conscious intention on the part of the insect; the extremely complex movements are carried out without any previous education, and only occur once in a lifetime. They are examples of complex reflex action. There are many others in higher life. In Lloyd Morgan's charming work[2] there are some observations on the movements of young fowls. He points out that immediately after birth many of these animals perform the most complicated movements, with wonderful accuracy of inherited co-ordination. They at once walk about and peck at all small objects, while in the case of aquatic birds they take to the water almost as soon as they are born. The Duke of Argyll,[3] actually saw a young moor-hen dive down to escape some danger in the water, immediately after it had left the egg. Its muscular movements were as perfect as if it had been trained. Now, these animals had not gone through any period of education; they had but lately left the egg, and had therefore had no opportunity of acquiring skill in the use of their muscles.

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[1] "Natural History of Plants," translated by Oliver, vol. ii.

[2] "Habit and Instinct," London, 1896.

[3] *Contemporary Review*, 1875.

These are good examples of what have been called the congenital instinctive activities or inherited complex reflex action. These facts are brought before you, in order to show you instances of simple and complex acts of the kind; and it has to be remembered that there is no line of demarcation between simple reflex acts and those which are more complex. You all know that if you tickle the sole of the foot of a sleeping child, the child draws up the leg or kicks out. You further know when the functional integrity of the spinal cord is divided in any way, that on tickling the sole of the foot there is again a powerful response; it has been found in animals that this response can be produced with the greatest ease, and the amount differs very largely with the grade of development of the animal. The lower the animal, the greater the response. The higher the animal, the less the response. This simply means that the brain is developed at the expense of the lower portion of the nervous system. The brain is the progressive part of the nervous system. If the lower part is severed from the upper there are more complicated responses in the lower than amongst the higher animals. You know that, after a frog has been beheaded, if the sole of the foot is stimulated, there is at once a withdrawing of that foot; if it be held firmly, and stimulation be still applied to it, the animal will take its other foot and try to brush away the irritation. That is seen in many amphibians. Higher in the realm of nature the response is smaller. A rabbit, for instance, will draw away its foot, but will not make use of the opposite limb to get rid of the irritation.

Reflex action seems to have been first grasped by the celebrated philosopher Descartes. He was apparently the first to grasp the significance of the fact that if an object is brought somewhat suddenly towards the eye there is an involuntary response, that we know as winking.

Unzer in his "Principles," published in 1771,[1] and translated long afterwards by Laycock, deals in a most interesting manner with the effects of external impressions on the nerve-centres, and their results as seen in muscular movements. He clearly understood that such movements could be evoked by influences which did not reach the brain, and that their effects were experienced and transformed lower down.

Prochaska,[2] so far as is known to me, in 1784 elaborated for the first time the scientific conception of reflex action. He described in a manner which is most suggestive "the reflexion of sensorial into motor impressions," and mentioned "that this reflexion may take place, either with consciousness or without consciousness." This, however, is not all. Prochaska further indicated that many of these "reflexions" were independent of the brain, and due to the action of lower centres. Both of these men were far in advance of the times in which they lived, and their views unfortunately sank into forgetfulness.

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[1] "The Principles of Physiology," translated and edited by Thomas Laycock, *Syd. Soc. Translation*, 1851.

[2] "A Dissertation on the Functions of the Nervous System," translated and edited by Thomas Laycock, *Syd. Soc. Translation*, 1851.

Almost half a century after the appearance of Prochaska's work, Marshall Hall[1] brought into prominence a classification of different forms of nervous phenomena, and more particularly emphasised the excito-motor or reflex functions. These he described as being the result of an impression conveyed by an exciter nerve to a centre, and reflected back to a muscle or set of muscles by a motor nerve.

The difference of opinion between Prochaska and Marshall Hall seems to be this, that Marshall Hall regarded reflex action as something in which sensibility played no part. Prochaska simply defined it as one in which there might be total unconsciousness, and George Henry Lewes,[2] in his criticism, points out most clearly the distinction between want of sensibility and want of perception. Lewes asserted that sensibility must play an important part in reflex action. Some part of the animal must feel, and in consequence of the feeling there is a response. Sensibility is doubtless distributed over the whole nervous system, wherever there is a receptive nerve-centre, and this sensibility is absolutely essential to all reflex acts, yet it may nevertheless be unconscious. Sensibility then is present, but may be unperceived; that is to say, there may be no perception, in the higher centres, of what has taken place. Lewes[3] describes a triton whose spinal cord had been cut through about the middle of the body, so that the animal practically had two segments; when one of the hind legs was placed in a shallow vessel of water, on the edge of which the animal stood, it moved so as to bring the whole of the posterior segment into the water. It is clear that in such an instance the spinal cord must have some kind of selective activity.

It is obvious that, for the production of a reflex act, there must be a means whereby a stimulus is received, a path by which it is transmitted in a centripetal direction, a centre in which the stimulus causes some reaction process, a channel by which the resulting impulse is conveyed in a centrifugal direction, and provision for its elaboration in the form of muscular response. Translated into the phraseology of the day, reflex action depends upon the integrity of the reflex arc, composed of neurons belonging to the lower level. A stimulus received by the sensory arborisation of the neuron of the posterior root, is transmitted, by the contiguity of its dendrites, to the neuron of the anterior grey matter, whence it passes by the emergent axon to the corre-

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[1] *Phil. Trans.*, London, 1833; "Lectures on the Nervous System and its Diseases," London, 1836; "New Memoir on the Nervous System," London, 1843.

[2] "The Physiology of Common Life," Edin. and London, 1860.

[3] *Ibid.*, vol. ii. p. 253.

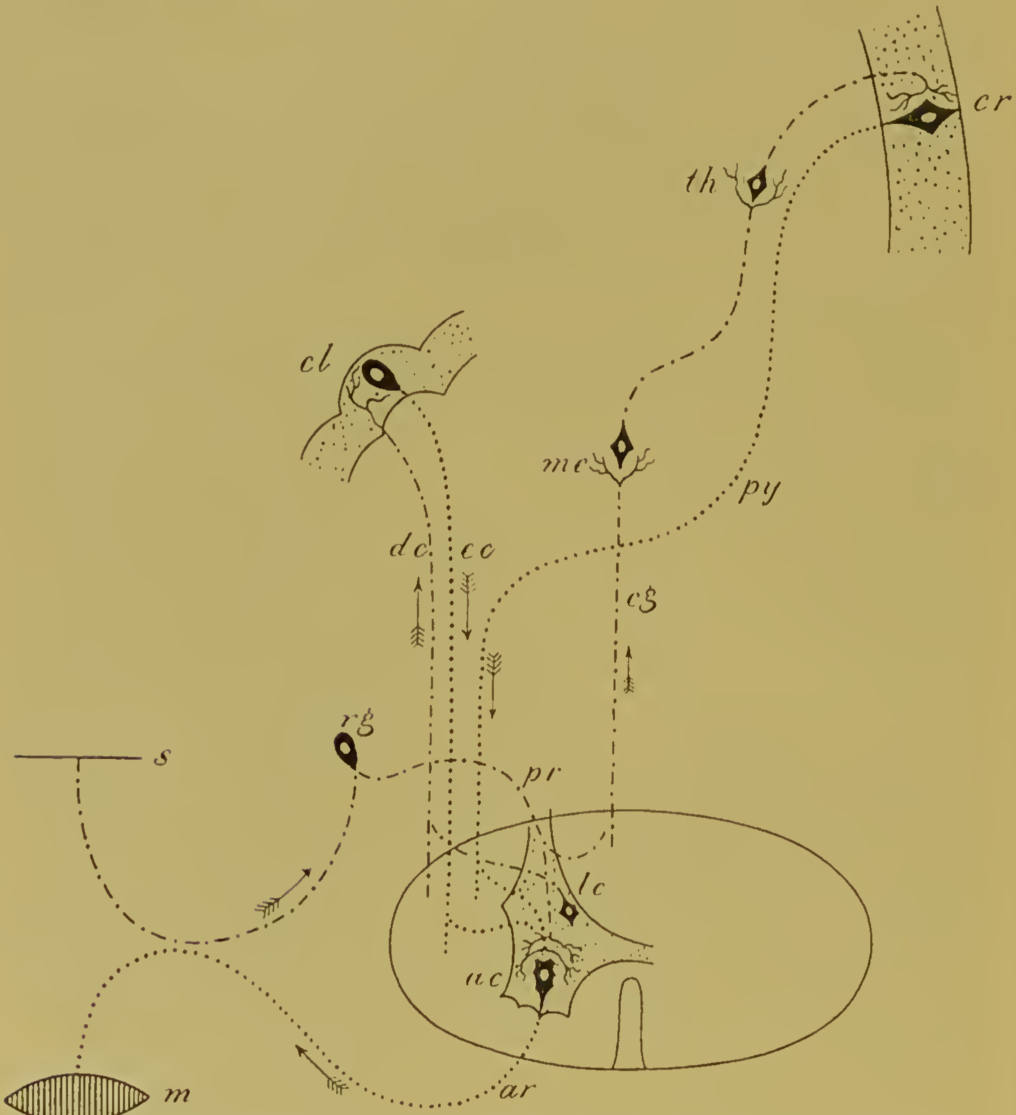

Fig. 1.—*s*, Afferent or sensory nerve; *rg*, ganglion of the posterior nerve root; *pr*, posterior nerve root; *ac*, anterior cornu; *ar*, anterior nerve root; *m*, efferent or motor nerve; *cg*, afferent cerebral tract; *me*, medulla oblongata; *th*, optic thalamus; *cr*, cerebral cortex; *py*, efferent cerebral tract; *dc*, afferent cerebellar tract; *cl*, cerebellar cortex; *cc*, efferent cerebellar tract; *lc*, Clarke's column.

sponding muscle or group of muscles. The neurons of the upper level, however, play an important part in ordinary reflex action by the exercise of a controlling influence. The neuron of the posterior root, under ordinary circumstances, transmits an impulse to the large neuron of the cortex, whence it is reflected downwards to the multipolar cell of the anterior spinal neuron. When these are rendered incapable of receiving and transmitting impulses, the reflex actions carried out by the neurons of the lower level become increased in their intensity. We know nothing of the effects arising from the centripetal neurons in this connection, but we know that any interference with the axon of the great cortical neuron increases reflex action. Thus the conclusion is obvious, that the upper level neurons exert a controlling or inhibitory influence upon those of the lower level. This, however, is not all. Lesions of certain portions of the brain, instead of increasing the reflexes, cause their diminution, or even their total abolition. This seems only explicable in the manner suggested by Gowers,[1] that there is a still higher mechanism, by means of which the neurons which habitually inhibit reflex action are themselves controlled.

Reflex action plays a very important part, not merely in vital processes, but in those by which we adapt ourselves to our surroundings. It is customary to divide the different reflexes, so called, into three distinct categories—those which are organic, or on which life itself depends; those which are cutaneous or superficial, by which we largely adapt ourselves to our surroundings; and, finally, those called the deep reflexes, which are intimately associated with the integrity of the muscular system.

The reflexes commonly called organic are those by which the life of the higher animals is largely subserved, and the processes of digestion, of circulation, of respiration, are carried out by these organic reflexes. Some of these functions, such as those of deglutition and of evacuation, are very closely bound up with the central nervous system indeed, and thus come to be of great value to us, from the point of view of diagnosis. Others are much less under the control of the central nervous system, and do not therefore affect so particularly the diagnosis of disease.

The cutaneous reflexes, by means of which the body is very largely brought into relationship with its environment, consist in muscular movements, in response to stimuli applied to the skin. The movement is usually single, but may be complex; it is more or less extensive, according to the general condition of the individual, the nature of the stimulus, and the region to which it is applied. According to physiological facts of universal acceptance, the interval of time which elapses between the stimulus and the response varies between ·05 and ·09 second. Such responses are in every sense truly reflex in their origin.

The muscle and tendon responses, first carefully investigated by Erb and Westphal, stand upon another plane. They are contractions of muscles produced by mechanical stimuli. The muscles must be in a condition of moderate, yet involuntary tension. These responses have been the subject of much discussion; by some observers they have been regarded as true reflex actions, and have thus been termed tendon reflexes, while other authors have held them to be direct responses, and have given them names which do not beg the question, such as knee-jerk, tendon response, or other names of no special import.

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[1] "Diseases of the Nervous System," 1899, vol. i., third edition.

One of the most important considerations in this discussion is concerned with the interval of time elapsing between the stimulus and the response. Tschirjew,[1] Gowers,[2] and Waller[3] have found that the time interval in the case of the knee-jerk is a little over ·03 second. Now it is well known that the time which would be required for the production of the knee-jerk, if it were a true reflex act, would be from ·06 to ·07 second.

Quite recently, Gotch[4] has carried out some most instructive investigations on the same subject. In order to determine the characters of the muscular contraction, he did not employ the whole limb, but the vastus internus, which, as Sherrington[5] showed, plays an important part in the production of the knee-jerk.

A rabbit having been etherised and fixed, the skin was divided, and the vastus internus muscle defined. That portion of the common tendon with which its fibres are associated was then detached from the patella and cut across, so that the muscle could be separated from its neighbours.

The tibial end of this muscular strip was attached to one arm of a lever by a thread which traversed a small pulley. The thigh was then fixed, and the vastus itself steadied by passing under its deeper part a piece of cork. To this cork the muscle was carefully attached by pins, whilst the cork was fixed to a rigid stand. By this arrangement the vastus muscle attached to the lever was independent of any passive movements of the tibia, and the recording lever was in no way affected by the shake caused by a tap on the patella or its ligament.

The partially separated slip of muscle was seen to contract throughout its whole length every time the ligamentum patellæ was struck with the knee flexed. Each contraction, when recorded, was found to be such as is obtained from a single twitch of the muscle, evoked either directly or indirectly in response to a single electrical stimulus of the muscle or its nerve. The twitch in response to the tendon tap occurred, whether the separated vastus was stretched taut by a weight, or allowed to lie lax upon the other muscles of the thigh. One essential factor in its production is a degree of permanent pull upon the unaltered portion of the ligamentum patellæ. This exerts a constant tension upon the upper fibres of the vastus muscle; on cutting off the whole ligament the response fails, but returns as the tendon is stretched.

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[1] *Arch. f. Psychiat.*, Berlin, 1878.

[2] *Med.-Chir. Trans.*, London, 1879.

[3] *Brain*, London, 1880; and *Journ. Physiol.*, Cambridge and London, 1890.

[4] *Journ, Physiol.*, Cambridge and London, 1896.

[5] *Proc. Roy. Soc. London*, 1893.

The contraction of the strip, in response to the tendon tap, was influenced by conditions, of which the following were the most important:—(1) The general condition of the animal, deep narcosis abolishing it; (2) the condition of the patellar tendon, the stretching of the tendon by flexing the knee being essential for its maintenance; (3) the integrity of the reflex arc associating the muscle through its motor nerve with sensory impulses; any impairment in these nervous connections abolished it. The strip contraction was thus undoubtedly a portion of such muscular activity as produces the well-known knee-jerk.

The unavoidable loss of time from mechanical and other factors is calculated by Gotch as being about ·002 second. From a long series of observations he has found that the response to a tap on the patellar tendon is very short, being only ·005 second, and as from this the error has to be deducted, we may conclude that the contraction follows the stimulus after so brief a period as ·003 second. It is quite clear that the reaction of the vastus to the tendon tap cannot be brought about by stimulation of its motor nerves, and still less by reflex excitation; the time for either is far too short. The reaction can only be the result, therefore, of direct mechanical stimulation of the muscle, probably from sudden stretching by the blow on the patellar tendon. The results of Gotch thus confirm Waller's conclusions.

It seems that the excitability of the vastus muscle is maintained by the presence of the reflex arc; and if so, then the reaction, though direct in its origin, is only possible when the muscular excitability has been brought up to and maintained at an adequate pitch. This is effected, under normal circumstances, by nervous influences descending constantly to it from the spinal cord. The experimental proof of this view is, however, wanting. It should be possible to obtain demonstrable evidence of alteration in the excitability of the vastus muscle, occurring in consequence of central nervous influences. All endeavours to reinstate the response after its abolition by section of the anterior crural, by such agents as electrical stimulation of the nerve, have failed, as shown by Tschirjew.[1]

That the response is direct, is conclusively proved by another series of observations, also published in the same paper. It is well known that a crossed response is sometimes observed, the direct knee-jerk on the side excited being followed by a contraction of the muscles on the other side. This has been the subject of some interesting researches by Gotch. The tracing, which is here reproduced, shows three curves—the upper gives the moment of producing the tendon tap; the lower shows the direct contraction of the vastus internus of the limb stimulated;

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[1] *Arch. f. Psychiat.*, Berlin, Bd. viii.

the middle gives the response of the vastus internus of the opposite side.

The average result was, that an interval of ·025 second occurred between the stimulus and the response on the same side, while an average delay of ·110 second took place between the stimulus and the contraction on the opposite side. It is impossible to doubt that, while the response on the side excited is a direct effect of the stimulus, that on the other side is a true reflex.

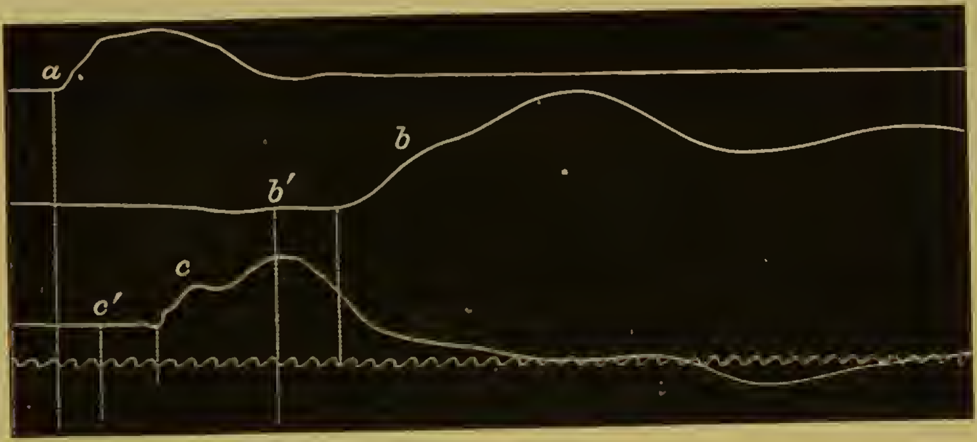

FIG. 2.

Such are the facts of those responses, direct and indirect, by which the body is brought into relation with its surroundings. Every day of our work in the wards of the Royal Infirmary you will be brought face to face with the modifications of these actions during our systematic analysis of the symptoms of our patients, and it will then be my duty to point out to you in detail the different features of these phenomena in various regions.